

CORRELATION AND ENRICHMENT OF TELEPHONE SYSTEM CALL DATA RECORDS

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FIELD OF THE INVENTION

The present invention relates generally to telephone systems and, more particularly, to the correlation of calling records.

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BACKGROUND OF THE INVENTION

1. Introductory Remarks:

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In the telephone system post-divestiture environment, complex regulatory tariffs have been mandated and/or inter-carrier contracts have been negotiated between carriers which (a) regulate the way in which traffic is to be routed between them and (b) specify the rates at which various types of traffic are to be charged. It is often of financial advantage to mis-route calls in violation of these existing regulatory tariffs and/or established inter-carrier contracts. The common name for this manipulation is "arbitrage". The intent of those perpetrating this mis-routing is to take advantage of lower rates associated with the delivery of telephone traffic via other than the proper routes. Confirming the presence of arbitrage and proper billing is often difficult due to the fact that call routing information is often missing or incomplete.

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2. Definitions:

In general, the following definitions are common in the telephone industry, but are included herein for completeness and clarity of explanation. They define the meanings of these terms as used in the Present Patent Document.

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Access Traffic -

A compensation mechanism governed by tariffs and/or contracts for message traffic

carried by interexchange carriers (IXC) and exchanged between the IXC's and local exchange carriers (LEC's), independent local exchange carrier (ILEC's), and competitive local exchange carrier (CLEC's). This type of traffic is generally carried over a type of telephone trunk called a Feature Group D trunk or FG-D trunk, and typically carries the highest per-minute charge. Under access traffic, IXC's pay the other carriers for each Minute of Use (MOU) of traffic destined to the IXC or originating from the IXC.

ACM timestamp -

The time at which the telephone being called began alerting the user (e.g. ringing).

Address Complete Message (ACM) -

The Address Complete Message (ACM) is used to acknowledge receipt of an initial address message (IAM) and to indicate that the called party is being alerted (e.g. via ringing).

ANM timestamp -

The time the operator of the telephone being called answered the telephone.

Answer Message (ANM) -

The Answer Message (ANM) is used to indicate that the user called has answered, end to end connection is established, and a conversation takes place.

Arbitrage -

As used herein and as commonly used in the telephone industry, it is the mis-routing of inter-carrier telephone calls in such a way as to violate existing regulatory tariffs and/or established inter-carrier contracts. The purpose of such mis-routing is typically to take advantage of lower rates associated with the delivery of telephone traffic via routes other than those established and required by such tariffs and contracts and as such may be fraudulent. Arbitrage typically occurs via the following techniques: (1) interexchange carrier (IXC) access traffic delivered via competitive local exchange carriers (CLEC's) and (2) transit traffic delivered via non-transit trunks

5 **Call Detail Record (CDR) -**

Called Number -

Calling Number -

15 Carrier Identification Code (CIC) -

Carrier Identification Code Parameter -

Charge Number -

Competitive Local Exchange Carriers (CLEC) -

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Destination Point Code (DPC) -

The Signaling System 7 (SS7) node [e.g switching office or Signaling Transfer Point (STP)] that the message is being sent to.

eo -

- 5 A switching office normally referred to as an end office or "eo" to which telephones (from homes or businesses) are connected via wires called "loops".

Feature Group D Trunk (FG-D Trunk) -

A type of telephone trunk. See Access Traffic.

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Forward Interwork Parameter -

An indicator as to whether Signaling System 7 (SS7) and non-SS7 inter-working was encountered prior to the point in the call where the parameter is observed.

- 15 **IAM timestamp -**

The time the trunk was seized for transmission of an SS7 message.

Independent Local Exchange Carriers (ILEC) -

- 20 Generally refers to a local exchange carrier (LEC) which co-existed with a local exchange carrier owned by the Regional Bell Operating Companies.

Initial Address Message (IAM) -

- 25 The Initial Address Message (IAM) is used to indicate the desire to set up a call. A trunk is seized and "reserved" for use in the call.

Interconnect Carrier -

Any carrier that interconnects with the local exchange carrier (LEC).

Interexchange Carriers (IXC) -

- 30 An interexchange carrier (IXC) transports calls from one local exchange carrier (LEC) to another, or possibly the same LEC, throughout the IXC's serving area. The IXC's

serving area would typically span more than one local access transport area (LATA), and the IXC receives messages from and delivers messages to local exchange carriers (LEC's, CLEC's, and ILEC's) and other interchange carriers (IXC's). Calls that span local area transport areas (LATA's - geographical regions defined at divestiture) typically must use an IXC.

IXC Trunk -

A trunk that comes from an interexchange carrier to a local exchange carrier.

Jurisdiction Indicator Parameter -

A parameter contained in SS7 messages which, if available, indicates the geographic origin of a call.

Link Monitoring System (LMS) -

A system that can be used to collect Call Detail Records (CDR's) by monitoring SS7 links.

Local Access Transport Area (LATA) -

The geographic area within which a local exchange carrier (LEC) provides service is typically divided into various areas referred to as local access transport areas (LATA's).

Local Exchange Carrier (LEC) -

A local exchange carrier (LEC) is a telephone service provider that provides telephone service to its customers in a specific geographical serving area. A local exchange carrier (LEC) would typically be a local telephone company.

Local Exchange Routing Guide (LERG) -

A document defining the specific local access transport area (LATA) within which a given telephone number is located.

Location Routing Number (LRN) -

A number obtained from the database at the service control point (SCP). The SCP converts the called number into the LRN which is the number used by the network to get the call to its final destination.

5 **Loop -**

Telephones are connected (from homes or businesses) via wires called "loops" to a switching office normally referred to as an end office or "eo".

Meet-Point Billing -

- 10 Traffic exchanged between interexchange carriers (IXC's) and independent local exchange carriers (ILEC's) destined for local exchange carrier (LEC) customers (in cases where the IXC does not directly interconnect with the LEC) is governed by tariffs and/or contracts, using a compensation mechanism referred to as meet-point billing. Under meet-point billing, IXC's pay
- 15 the ILEC a fee, part of which is subsequently paid by the ILEC to the LEC for each Minute of Use (MOU) of traffic between the IXC and the LEC.

Minute of Use (MOU) -

- For billing purposes a measure of the time which a given carrier's resources are
- 20 consumed providing a given service.

Numbering Plan Address (NPA) -

More commonly known as the area code of the telephone number.

25 **NPANXX -**

The numbering plan address (i.e., the area code) plus the next three digits of the telephone number.

Originating Point Code (OPC) -

- 30 The Signaling System 7 (SS7) node [e.g. switching office or Signaling Transfer Point (STP)] that is sending the message.

Reciprocal Compensation -

Under reciprocal compensation, carriers pay each other a usage fee for each Minute of Use (MOU) of traffic delivered from their network to the other carrier's network. This message traffic is typically traffic exchanged between various local exchange carriers (LEC's) and their competitive local exchange carriers (CLEC's) and independent local exchange carriers (LEC's). This type of traffic is generally carried over a type of telephone trunk called a local trunk.

Release Complete Message (RLC) -

The Release Complete Message (RLC) is sent when the second of the two connected parties hangs up. At that point the trunk is released.

Release Message (REL) -

The Release Message (REL) indicates that the first of the two connected parties has hung up.

REL timestamp -

The time the operator of the first telephone to hang up did so.

Remote Site Processors -

A device used to consolidate partial Call Detail Records (CDR's) into complete CDR's.

RLC timestamp -

The time the operator of the second telephone to hang up did so.

Service Control Point (SCP) -

A network database used to translate called numbers into local routing number which translates the called number in the location routing number (LRN).

Signaling Transfer Points (STP's) -

At the heart of the SS7 network are packet switches known as Signaling Transfer Points (STP's). STP's are deployed in pairs in the North American SS7 network to provide communication path redundancy. Different carriers own a portion of the SS7 network and interconnect their end offices (eo's) and tandem's to the overall SS7 network so as to enable end-to-end communication between carriers.

SS7 Links -

The communication links over which Signaling System 7 (SS7) traffic is carried.

SS7 Network -

The Signaling System 7 (SS7) messages are transported over a secure data network referred to as the "SS7 network". The SS7 network comprises various SS7 Links along with Signaling Transfer Points (STP's).

SS7 Protocol -

To perform the task of call setup and tear down when multiple end offices (eo's) are involved, switching offices communicate with each other using a signaling protocol referred to as Signaling System 7 (SS7), carried over SS7 links. SS7 messages are used in specific sequences to perform various tasks required to establish telephone connections. Telephone calls between two customers connected to the same eo will be handled by the application logic contained in the eo, and will not require the use of the SS7 protocol.

Tandem -

In certain cases, for example two towns that are somewhat far apart, a type of switching center called a "tandem" is involved in establishing connectivity between two customers.

TCIC -

Trunk Circuit Identification Code. Between any two telephone switches there may a trunk group which comprises several trunks. These trunks are identified via the TCIC.

SUMMARY OF THE INVENTION

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The present patent document discloses novel methods for the correlation of calling records and for the detection of mis-routing of traffic in a telephone or other communication system. Previous methods for detection of mis-routing have been based upon a single call sample, e.g. a call record obtained at the point where the call originates or at the point where the call terminates. The information available within a single call record has limitations due to the fact that critical routing information may be (a) missing or (b) incorrect, and these techniques have proven to be ineffective at determining the presence of arbitrage. Correlation of call detail records obtained from various communication segments provides the ability to mutually enrich the records so as to increase billing accuracy as well as to enhance the detection of call mis-routing.

Techniques disclosed in the present patent document can be used to identify inter-carrier telephone calls that are being mis-routed in such a way as to violate existing regulatory tariffs and/or established inter-carrier contracts. The common name for this manipulation is "arbitrage", and the intent of the perpetrators is to take advantage of lower rates associated with the delivery of telephone traffic via routes other than those legislated or contracted. Through the process of correlation in representative embodiments, various call "legs" associated with the same call can be identified, and a more accurate "compound" call record can be made that incorporates call routing information obtained from the individual call legs.

In a representative embodiment, a basic approach to arbitrage detection is to correlate inbound calls from a competitive local exchange carrier (CLEC) to a local exchange carrier (LEC) with the corresponding outbound calls at their point of origin. Correlation can be obtained via a variety of data obtained from call detail records in the SS7 network.

The correlation feature of the link monitoring system (LMS) is the primary tool used to implement arbitrage detection. Call detail records (CDR's) are collected throughout the LEC footprint and "correlated" at the time of their load into the call detail record database. The correlation method comprises identifying call segments via call detail records wherein (1) the called station numbers are identical and (2) the time of call

initiation and the time the first party hangs up match within a configurable, but very small, time difference. The correlation method typically applies different time thresholds depending upon whether the call segments being correlated are deemed to be adjacent (e.g. on either side of a tandem), or non-adjacent (e.g. more than two tandems away from each other).

In order to eliminate false correlations (i.e., to disassociate call segments that really are not related to the same call), attempts are made to increase the correlation confidence by correlating other pieces of call setup information from the various call segments. Specifically, further efforts can be made to (1) confirm that the time the connection for the call was completed matches within a configurable, but very small, time difference, (2) insuring that the calling number information parameters match, (3) insuring that charge number information parameters match, and/or (4) insuring that jurisdiction information parameters match.

Additional constraints can be applied to select calls that fit the criteria of arbitrage, and to exclude calls that may be correlated for other legitimate reasons or duplicate call segments that may have been collected due to over-provisioning of the link monitoring systems.

A measure of the probability of arbitrage is based upon the combinations of characteristics that are present. Once suspected, SS7 call detail records are randomly chosen and compared with billing records to confirm arbitrage. Once arbitrage is confirmed, the characteristics of known arbitrators can be further refined. Traffic profiles of carriers can be created that contain historical traffic information. Arbitrage may be suspected whenever the traffic profiles of two or more carriers change in ways inversely proportional to each other, suggesting the redirection of traffic from one carrier to another. Once suspected, SS7 call detail records can be analyzed in further detail to confirm the arbitrage.

Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

similar communication system as described in various representative embodiments of the present patent document.

Figure 2D is a drawing of a system for accumulating call detail records into a central data repository.

5 Figure 2E is a flow chart of a representative method for detection of arbitrage in the telephone or similar communication system as described in various representative embodiments of the present patent document.

10 Figure 3A is a drawing of a representative example of call routing in the telephone or similar communication system without arbitrage as described in various representative embodiments of the present patent document.

Figure 3B is a drawing of a representative example of call routing in the telephone or similar communication system with arbitrage as described in various representative embodiments of the present patent document.

15 Figure 4 is a flow chart of a method for correlating call detail records as described in various representative embodiments of the present patent document.

Figure 5 is a flow chart of additional method steps for correlating call detail records as described in various representative embodiments of the present patent document.

20 Figure 6 is a flow chart of a method for establishing a probability of arbitrage in the telephone or similar communication system as described in various representative embodiments of the present patent document.

Figure 7 is a flow chart of another method for establish the probability of arbitrage in the telephone or similar communication system as described in various representative embodiments of the present patent document.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in the drawings for purposes of illustration, the present patent document discloses novel methods for the correlation of calling records and for the detection of mis-routing of traffic in a telephone or other communication system. Previous methods for detection of mis-routing have been based upon a single call sample, e.g. a call record obtained at the point where the call originates or at the point where the call terminates. The information available within a single call record has limitations due to the fact that critical routing information may be (a) missing or (b) incorrect, and these techniques have proven to be ineffective at determining the presence of arbitrage. Correlation of call detail records obtained from various communication segments provides the ability to mutually enrich the records so as to increase billing accuracy as well as to enhance the detection of call mis-routing. In the following detailed description and in the several figures of the drawings, like elements are identified with like reference numerals.

1. Introductory Comments:

Techniques disclosed in the present patent document can be used to identify inter-carrier telephone calls that are being mis-routed in such a way as to violate existing regulatory tariffs and/or established inter-carrier contracts. The common name for this manipulation is "arbitrage", and the intent of the perpetrators is to take advantage of lower rates associated with the delivery of telephone traffic via other routes. Through the process of correlation in representative embodiments, various call "legs" associated with the same call can be identified, and a more accurate "compound" call record can be made that incorporates call routing information obtained from the individual call legs. Other techniques disclosed herein can be used to correlate call data records created in one part of the network with call detail records created in another part. Such techniques have application in calling traffic, detection of call mis-routing, and call billing.

2. The Telephone System Environment:

A local exchange carrier (LEC) operates in and serves individual telephone

subscribers in a specific geographical serving area. The serving area is typically divided into Local Access Transport Areas (LATA's). The LEC interconnects to competitive local exchange carriers (CLEC's), Independent local exchange carriers (ILEC's) and Interexchange Carriers (IXC's) throughout its serving area.

5 Traffic exchanged between IXC's and LEC's/ILEC's/CLEC's is governed by tariffs and/or contracts, using a compensation mechanism referred to as access traffic. Under access traffic, IXC's pay the other carriers for each Minute of Use (MOU) of traffic destined to the IXC or originating from the IXC. This type of traffic is generally carried over a type of telephone trunk called a Feature Group D trunk or FG-D trunk, and
10 typically carries the highest per-minute charge.

Traffic exchanged between CLEC's and LEC's and between ILEC's and LEC's is typically governed by tariffs and/or contracts, using a compensation mechanism referred to as reciprocal compensation. Under reciprocal compensation, carriers pay each other a usage fee for each Minute of Use (MOU) of traffic delivered from their network
15 to the other carrier's network. This type of traffic is generally carried over a type of telephone trunk called a local trunk.

Traffic exchanged between IXC's and ILEC's destined to LEC customers (in cases where the IXC does not directly interconnect with the LEC) is governed by tariffs and/or contracts, using a compensation mechanism referred to as meet-point billing.
20 Under meet-point billing, IXC's pay the ILEC a fee, part of which is subsequently paid by the ILEC to the LEC for each Minute of Use (MOU) of traffic between the IXC and the LEC.

3. Overview of Telephony, SS7, and Call Detail Records:

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3.1 Basic Telephony

Telephones are connected (from homes or businesses) via wires called "loops" to a switching office normally referred to as an end office or "eo". Telephone calls between two customers served by the same eo is handled by the application logic
30 contained in the eo and will not require the use of the SS7 protocol described in the following.

When telephones are served from different eo's (e.g. in different towns), they must be interconnected via wires called "trunks" between the eo's. This type of telephone call will require inter-office coordination, usually via a networking protocol called SS7.

5 In certain cases, for example two towns that are somewhat far apart, another type of switching center called a "tandem" is also involved in establishing connectivity between two customers.

To satisfy various regulatory requirements, telephone carriers are classified as either "exchange carriers" (e.g., CLEC's) or "interexchange carriers" (e.g. IXC's). Calls
10 that span Local Area Transport Areas must use an interexchange carrier.

To perform the task of call setup and tear down (when multiple eo's are involved), switching offices communicate with each other using a signaling protocol referred to as Signaling System 7 (SS7), carried over SS7 links. SS7 messages are used in specific sequences to perform various tasks required to establish telephone connections. The SS7
15 messages are transported over a secure data network separate from the telephone call connection and referred to as the "SS7 network". At the heart of the SS7 network are packet switches known as Signaling Transfer Points (STP's). STP's are deployed in pairs in the North American SS7 network to provide communication path redundancy. Different carriers own a portion of the SS7 network, and interconnect their eo's and
20 tandem's to the overall SS7 network to enable end-to-end communication between carriers SS7 messages consist of a message type and associated parameters. In a representative embodiment, figures 1A-1F below illustrate the use of SS7 in the basic setup and tear down of telephone calls. For clarity of illustration, the configuration described in figures 1A-1F only comprises two eo's. The example is intended for
25 illustrative purposes only. Other switching points and communication lines could be involved in any given connection between two stations.

Figure 1A is a drawing of a telephone or similar communication system **100** as described in various representative embodiments of the present patent document. Figure 1B is a drawing of the telephone or similar communication system **100** in preparation for
30 call connection as described in various representative embodiments of the present patent document. Figure 1C is a drawing of the telephone or similar communication system **100**

first loop **110**), as well as the trunk **120** seized to connect first and second switching offices **115,116** is indicated in figure 1B by bold lines. A second message **155**, which in the SS7 system **130** is referred to as address complete message (ACM) **155**, is sent from the second switching office **116** via signal links **135** and transfer point **140** of signaling system **130** to acknowledge receipt of the IAM **150** and to indicate that the called station **106** is being alerted (e.g., via ringing).

In figure 1C, a third message **160**, which in the SS7 system **130** is referred to as an answer message (ANM) **160**, is sent from the second switching office **116** via signal links **135** and transfer point **140** of signaling system **130** to the first switching office **115** to indicate when the called station **106** has answered. End to end connection is then established, and a conversation can take place. Connection between calling station **105** and first switching office **115** (i.e., first loop **110**), between first and second switching offices **115,116** via the trunk **120**, and between second switching office **116** (i.e., second loop **111**) and called station **106** is indicated in figure 1C by bold lines.

In figure 1D, a fourth message **165**, which in the SS7 system **130** is referred to as a release message (REL) **165**, is sent from one of the switching offices, in this example the first switching office **115** via signal links **135** and transfer point **140** of signaling system **130** to the second switching office **116** to indicate that one of the parties, in this example calling station **105**, has disconnected from the established communication link. In other words, the calling station **105** hung up. Connection between first and second switching offices **115,116** via the trunk **120** and between second switching office **116** (i.e., second loop **111**) and called station **106** is indicated in figure 1D by bold lines.

In figure 1E, a fifth message **170**, which in the SS7 system **130** is referred to as a release complete message (RLC) **170**, is sent from one of the switching offices, in this example the second switching office **116** via signal links **135** and transfer point **140** of signaling system **130** to the first switching office **115** to indicate that one of the parties, in this example called station **106**, has disconnected from the established communication link. Again in other words, the called station **106** hung up. Connection between first and second switching offices **115,116** via the trunk **120** is indicated in figure 1E by bold

lines. At that point the trunk **120** is released as indicated in figure 1F.

3.2 SS7 Messages:

5 Signaling transfer points **140** in the SS7 network **130** transport the SS7 messages along with various parameters used through-out the call set up process to not only produce the desired connections, but also to enable all the switching offices involved to obtain measurements that can later be used to accurately bill the customers involved. Table 1 identifies key parameters comprising call detail records **T100**. Call detail records **T100** are also referred to herein as CDR's **T100**, data records **T100** and as records **T100**. Of
10 particular interest in Table 1 are (1) the calling number **T110** of the user (station) making the call, (2) the charge number **T120** of the user (station) making the call, (3) the SS7 node that is sending the message **T130**, also referred to herein as jurisdiction information parameter **T130**, (4) a forward interworking parameter **T140**, (5) the backward interworking parameter **T150**, (6) the SS7 node that the message is being sent to **T160**,
15 also referred to herein as carrier identification code **T160**, and (7) the number dialed by the user **T170**.

 Certain timestamps associated with the dates and times at which each SS7 message is detected are also recorded as shown in Table 2. Of particular interest in Table
20 2 are (1) an initial address message (IAM) timestamp **T210**, also referred to herein as first timestamp **T210**, (2) a release message (REL) timestamp **T220**, also referred to herein as second timestamp **T220**, and (3) an answer message (ANM) timestamp **T230**, also referred to herein as third timestamp **T230**.

3.3 Call Detail Records (CDR's):

25 The parameters and time-stamps associated with each message or collection of information referred to as the call detail record **T100**, as shown in Tables 1 and 2, are the primary pieces of information needed to determine who called whom, how the call was routed and what the call disposition was.

 For the illustrative purposes of this description, we will ignore other parameters
30 that are used to handle more complex telephony services such as: Operator assisted calls, forwarded calls, 800 service, Local Number Portability, etc

The following discussion describes the functionality and mechanisms relating to the matching of records **T100** relating to the same underlying telephone call. This matching of records **T100** has applications in traffic routing analysis, interconnection billing, and the detection of mis-routed traffic or arbitrage. For example, in call routing analysis the records **T100** can be used to identify the path of calls through a network **100**. It can be used to relate a call flowing between multiple networks, e.g. leaving a local network flowing through an external network and reappearing at the same or another local network. For call routing efficiency, as well as billing purposes and arbitrage detection, it is important to identify the route that the call followed.

3.3.1 Call Detail Record Correlation Techniques:

In a representative embodiment, call detail records (CDR's) **T100** are specified as being correlated based upon criteria comprising the following elements: (1) a combination of time differences between potentially related events observed at different points in the network which can differentiate between alternate paths through the network (e.g., single tandem, multiple tandem, internetwork call), (2) partial and full addressing parameter matching (such as a called telephone number **T170**), (3) identification of calls traversing a single switch by a common point code in the destination and originating point codes **T160**, **T130** of two records **T100**, and (4) use of additional fields to increase confidence of record matching (e.g., using calling and charging number matching). From the above items a correlation confidence is obtained which can be used to indicate the degree of similarity of call leg records **T100** which could be used, for example, to overcome the masking techniques employed to bypass access charges such as masking part of all of the calling and/or charge party identifiers **T110**, **T120** or though the introduction of a new/altered partial or full calling and/or charge identities.

3.3.2 Duplicate Call Detail Records:

Duplicate records **T100** are defined to be two or more call records **T100** relating to the same call leg between any two directly connected network element nodes. These are detected based on the presence of matching point code (originating **T130** and

destination **T160**) and identical trunk circuit identifiers in addition to the event timestamps closely matching.

3.3.3 Data Enrichment of Call Detail Records:

5 Using related call records **T100**, fields can be copied forward to earlier related records **T100** to indicate information added as the call traversed a network **100** - e.g. to indicate to earlier related call records **T100** the ultimate destination of a call. Or can be used to compensate for data that has been inadvertently or intentionally lost/masked in later related call records **T100** by copying that masked data from earlier related call records **T100**. Specifically, (1) the calling number **T110** can be copied into later related call leg records **T100** to indicate the true origination of a call. This can be employed for improved billing accuracy and detection of access charge bypass (arbitrage) and (2) the local routing number (LNP) of a “dumped” or pre-translated ported call can be copied back to earlier call legs of the same call which may have been prior to the LNP query/translation, this enables the ultimate destination to be available to earlier records.

15 Figure 2A is another drawing of the messaging system of the telephone or similar communication system **100** as described in various representative embodiments of the present patent document. In the representative embodiment of figure 2A, a first signaling path segment **261** is connected to a first signaling transfer point **271** indicated in figure 2A as S1; the first signaling transfer point **271** is connected to a second signaling path segment **262**; the second signaling path segment **262** is connected to a second signaling transfer point **272** indicated in figure 2A as S2; the second signaling transfer point **272** is connected to a third signaling path segment **263**; the third signaling path segment **263** is connected to a third signaling transfer point **273** indicated in figure 2A as S3; and the third signaling transfer point **273** is connected to a fourth signaling path segment **264**. In the SS7 network **130**, the signaling path segments **261,262,263,264** are used to transport messages or signals required by the telephone system **100** to connect the calling station **105** to the called station **106**, thereby completing the call and permitting communication between calling station **105** and called station **106**, as well as to subsequently disconnect the call. Signaling transfer points **271,272,273** route the call messages to the appropriate signaling path segments **261,262,263,264**. Copies of the call

records **T100** created during call creation are sent to a central data repository **215** as shown in figure 2D and as will be discussed with that figure. In the example of figure 2A, a first call data record **281** is created at a first call record creation point **291**, and a second call data record **282** is created at a second call data creation point **292**.

5 Figure 2B is yet another drawing of the messaging system of the telephone or similar communication system as described in various representative embodiments of the present patent document. In addition to the elements shown in figure 2A, figure 2B shows calling station **105** connected to an initial signaling path segment **260** which is connected to an initial signaling transfer point **270** and which is connected in turn to the first signaling path segment **261**. Also shown is called station **106** connected to a fifth signaling path segment **265** which is connected to a fourth signaling transfer point **274** which is connected in turn to the fourth signaling path segment **264**. Also as shown in figure 2B, a third call data record **283** is created at a third call data creation point **293**.

10 Further, in figure 2B the location routing number **297** corresponding to the called number **T170** is obtained from a network element database **295** also referred to as a service control point database **295**.

15 Figure 2C is a flowchart for separation of call data records **T100** in the telephone or similar communication system **100** as described in various representative embodiments of the present patent document. In block **298**, the call data records **T100** are separated in time order by arrival time at the central data repository **215** of figure 2D. Block **298** then transfers control to block **299**.

20 In block **299** the separated groups of call data records **T100** are sent to different processing units wherein parallel processing correlates the call data records **T100**. Parallel processing enables more rapid correlation.

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3.3.4 Efficiency of Correlation:

 A critical factor in the performance of a correlating call detail records **T100** is the reduction of the number of comparisons required to locate a candidate matching record **T100** and then establish the confidence of matching. In a representative embodiment, since call records **T100** arrive in approximately call release time at a central data base that is used to collect the system call detail records **T100**, they are ordered in time. Thus,

they require minimal sorting to result in a fully ordered record sequence in call release time order. Sets of call detail records **T100** can be grouped by time periods to enable parallel processing on a symmetric multiprocessing server.

5 In another representative embodiment, call detail records **T100** are separated into data streams according to the value of at least one digit in the called number **T170**. Typically the selected digit or digits are those rightmost in the number. As an example, if two digits are selected as the separation criteria, call data records for called number **T170** 312-465-6789 are separated first into the data stream identified by "89" in the called number **T170**. Note that in this example as many as 100 separate data streams
10 could be created with resultant reduction in record **T100** comparison time. The number of separations could also be selected to be less than 100 in this example.

3.3.5 Correlation Summary:

In the SS7 network **130**, signaling path segments **260,261,262,263,264,265**
15 transport SS7 messages through signaling path segments **260,261,262,263,264** along with various parameters used through-out the call set up process to not only produce the desired connections, but also to enable all the switching offices involved to obtain measurements that can later be used to accurately bill the customers involved.

20 3.3.6 Arbitrage Summary:

The arbitrage detection methods as disclosed in representative embodiments comprise two techniques: (1) correlation and (2) statistical analysis. In the correlation process, call detail records **T100** collected at the final leg of the call are correlated with call detail records **T100** collected on earlier legs of the call, of which there may be
25 numerous legs. Arbitrage is detected whenever a call initially directed to an interexchange carrier is later found to be delivered to the local exchange carrier via a means inconsistent with the delivery of interexchange traffic. In the statistical process, call detail records **T100** between two carriers are collected and analyzed to characterize the traffic with respect to certain key parameters. Arbitrage is suspected when the
30 characteristics match predefined patterns.

Call detail records **T100** can be collected using a variety of methods, including

the use of a Link Monitoring System (LMS), such as Agilent Technologies' acceSS7 system, although the basic elements of the present invention do not rely on a specific collection technique or specific vendor equipment. Link monitoring systems are designed to capture the SS7 call detail records **T100** as described in Table 1. Measurement equipment is deployed at each of the signal transfer point **140** locations, and "listens" to the SS7 messages being transported over the SS7 links **135**.

Figure 2D is a drawing of a system for accumulating call detail records **T100** into a central data repository **215**, also referred to herein as a call detail record data base **215**. Link monitoring systems detect the SS7 messages, timestamp them, and associate them into partial call detail records **T100**. At remote sites **205** processors consolidate partial call detail records **T100** into complete call detail records **T100**, and forward the completed call detail records **T100** in near real-time via a wide area network (WAN) **210** to a central data repository **215**, which could be for example a database that stores the call detail records **T100**. The call detail record database **215** is typically designed to store large quantities of call detail records **T100** for extended periods of time.

The quantity and breadth of information stored is dependent on the extent to which the link monitoring system (LMS) has been deployed on the carrier's network. In typical embodiments, it is sufficient to monitor all the SS7 links that provide interconnection between the local exchange carrier and other types of carriers, although additional coverage will provide more information that can be used to strengthen results of the analysis.

4. Overview of Arbitrage Detection:

Figure 2E is a flow chart of a representative method **250** for detection of arbitrage in the telephone or similar communication system **100** as described in various representative embodiments of the present patent document. In Block **220** of figure 2E, a first and second call records **T100** are selected, wherein the first and second call records **T100** both have the same called station **106**. Block **220** then transfers control to block **225**.

Block **225** establishes whether the first and second call records **T100** are correlated. Block **225** then transfers control to block **230**.

When first and second call records **T100** are correlated, block **230** transfers control to block **235**.

Block **235** establishes a measure of the probability of call mis-routing.

5 **5. Arbitrage Example:**

Figure 3A is a drawing of a representative example of call routing in the telephone or similar communication system **100** without arbitrage as described in various representative embodiments of the present patent document. In the representative example of figure 3A, a call originates from the calling station **105** located in a first local access transport area (LATA 1) **305**, also referred to herein as a first remote area **305**, to the called station **106** located in a second local access transport area (LATA 2) **306**, also referred to herein as a second remote area **306**. One call detail record **T100** will be captured by a link monitoring system **310** for each leg of the call, assuming the link monitoring system **310** equipment is monitoring the appropriate SS7 links. In this example of a call originating in one part of the LEC network (LATA 1 **305**) and ending in another part of the network (LATA 2 **306**) could result in as many as 4 monitored call detail record's as follows:

1. LEC eo **321** to LEC Tandem **322** in LATA 1 **305**
2. LEC Tandem **322** in LATA 1 **305** to IXC Tandem **323** in IXC network **307**
3. IXC Tandem **323** in IXC network **307** to LEC Tandem **324** in LATA 2 **306**
4. LEC Tandem **324** to LEC Eo **325** in LATA 2 **306**

Note that the call is not monitored as it traverses the IXC network **307**, because the IXC SS7 links are not part of the LEC network. In figure 3A, LEC tdm **322** means LEC tandem **322**, and LEC tdm **324** means LEC tandem **324**.

Figure 3B is a drawing of a representative example of call routing in the telephone or similar communication system **100** with arbitrage as described in various representative embodiments of the present patent document. In the representative

example of figure 3B, an arbitrage call is delivered at its destination via a competitive local exchange carrier (CLEC) 330, instead of being delivered via a local exchange carrier (LEC) tandem 324 in LATA2 306, as illustrated in figure 3A.

The last leg of the call above, from the CLEC 330 to the LEC eo 325 in LATA 2 306, could appear to be a simple originating call from a CLEC customer to a LEC customer. However, by matching this leg with one of the originating call legs (LEC eo 321 to LEC tandem 322 or LEC tandem 322 to interexchange carrier 323) in the LATA 1 305 area, it is possible to demonstrate that the final leg is really the continuation of an earlier call.

Often the information needed to correlate the final call leg to prior call legs is missing or has been altered at some point. In representative embodiments, techniques are disclosed herein to effect recovery of sufficient information to allow the final call leg to be positively correlated with an earlier call leg, proving that the final call leg represents an improper routing of the original call.

6. Representative Methods for Detection of Arbitrage:

In a representative embodiment, a basic approach to arbitrage detection is to correlate inbound calls from a competitive local exchange carrier (CLEC) to a local exchange carrier (LEC) with the corresponding outbound calls at their point of origin.

The correlation feature of the link monitoring system (LMS) is the primary tool used to implement arbitrage detection. Call detail records (CDR's) T100 are collected throughout the LEC footprint and "correlated" at the time of their load into the call detail record database 215. The correlation method comprises identifying call segments via call detail records T100 wherein (1) the numbers dialed by the user (i.e., the called station numbers) T170 are identical and (2) initial address message (IAM) 150 timestamps T210 and release message (REL) 165 timestamps T220 match within a configurable, but very small, time difference. The correlation method typically applies different time thresholds depending upon whether the call segments being correlated are deemed to be adjacent (e.g. on either side of a tandem), or non-adjacent (e.g. more than two tandems away from each other).

Figure 4 is a flow chart of a method for correlating call detail records T100 as

described in various representative embodiments of the present patent document. In block **405** a first call detail record **406**, not shown in the figures but of form similar to that of Table 1 with time stamps of Table 2, of an inbound call from a first local access transport area **305** to a second local access transport area **306** is selected. Block **405** then transfers control to block **410**.

In block **410** a second call detail record **407**, not shown in the figures but of form similar to that of Table 1 with time stamps of Table 2, of an inbound call from a first local access transport area **305** to a second local access transport area **306** is selected. Block **410** then transfers control to block **420**.

When the called station **106** of the first call detail record **406** is the same as the called station **106** of the second detail record **407**, block **420** transfers control to block **425**. Otherwise, block **420** transfers control to block **440**.

When the absolute difference between the time stamp of the IAM of the first call detail record **406** subtracted from the time stamp of the IAM of the second call detail record **407** is less than a preselected initial address message (IAM) time difference **411**, not shown in any of the figures and also referred to herein as a first time difference **411**, block **425** transfers control to block **430**. Otherwise, block **425** transfers control to block **440**.

When the absolute difference between the time stamp of the REL of the first call detail record **406** subtracted from the time stamp of the REL of the second call detail record **407** is less than a preselected release message (REL) time difference **412**, not shown in any of the figures and also referred to herein as a second time difference **412**, block **430** transfers control to block **435**. Otherwise, block **435** transfers control to block **440**.

Block **435** marks the first and second call detail records **406,407** as correlated. The method above is typically repeated for other combinations of call detail records **406,407**.

Block **440** marks the first and second call detail records **406,407** as uncorrelated. Once again, the method above is typically repeated for other combinations of call detail records **406,407**.

Call detail records **406,407** are typically checked against the above method as

they are loaded into the central data repository **215** and are assigned the same correlation identification code if they are correlated. Note that it is possible for more than two call detail records to be correlated and assigned a single correlation identification code.

5 In order to eliminate false correlations (i.e., to disassociate call segments that really are not related to the same call), attempts are made to increase the correlation confidence by correlating other pieces of call setup information from the various call segments. Specifically, further efforts can be made to (1) identify ANM message time stamps that match within a configurable, but very small, time difference, (2) insuring that the Calling Number information parameters match, (3) insuring that Charge Number
10 information parameters match, and/or (4) insuring that jurisdiction information parameters match.

Figure 5 is a flow chart of additional method steps for correlating call detail records as described in various representative embodiments of the present patent document. The method steps of figure 5 are inserted between blocks **430** and **435** of
15 figure 4. When the absolute difference between the time stamp of the ANM of the first call detail record **406** subtracted from the time stamp of the ANM of the second call detail record **407** is less than a preselected ANM time difference **413**, not shown in any of the figures and also referred to herein as a third time difference **413**, block **505** transfers control to block **510**. Otherwise, block **505** transfers control to block **440**.

20 When the calling number **T110** of the first call detail record **406** is the same as the calling number **T110** of the second call detail record **407**, block **510** transfers control to block **515**. Otherwise, block **505** transfers control to block **440**.

When the charge number of the first call detail record **406** is the same as the charge number of the second call detail record **407**, block **515** transfers control to block
25 **520**. Otherwise, block **515** transfers control to block **440**.

When the jurisdiction of the first call detail record **406** is the same as the jurisdiction of the second call detail record **407**, block **520** transfers control to block **435**. Otherwise, block **520** transfers control to block **440**.

30 Additional constraints can be applied to select calls that fit the criteria of arbitrage, and to exclude calls that may be correlated for other legitimate reasons or duplicate call segments that may have been collected due to over-provisioning of the link

monitoring systems **310**. Specifically, the following calls typically may be excluded: Calls inbound to the LEC network (non-transit, destined to a LEC telephone number) from CLEC's in a given LATA that correlate with outbound calls to IXC's in a different LATA. The following calls are also typically excluded: (1) non-toll calls and special types of calls such as those that require a two step dialing process to complete, (2) duplicate call segments (same opc/dpc/tcic/iam, same call detail records, etc.), (3) local number portability calls which could represent legitimate routing with IXC delivering call to original CLEC number, and CLEC performing lookup and completing call to LEC, and (4) call forwarding calls where call forwarding takes place at the CLEC, and the resulting call to the LEC appears to have originated in another LATA.

Several methods can be used to (a) jurisdictionalize call segments within LATA boundaries and to (b) identify outbound IXC calls and (c) identify non-transit inbound CLEC calls.

Jurisdictionalization can be performed by (1) Using a look-up table based on the Local Exchange Routing Guide (LERG) to map the calling or called NPANXX to a specific State/LATA, (2) If the NPANXX is missing, assign a default NPANXX based on the point code of the switching system involved in the call, and then use a look up table based on the local exchange routing guide (LERG) to map the calling or called NPANXX to a specific state and/or LATA, and (3) reading the geographic identification contained within each call detail record **T100** that identifies the point in the network where the call detail record **T100** was collected, and use a look-up table to map this geographic location to a specific state and/or LATA.

Identification of Outbound LEC to IXC Calls can be performed by (1) using a look-up table to map the specific trunk used on an originating LEC call derived from another look-Up table mapping the triplet of OPC, DPC and TCIC, which are available within the SS7 IAM message to a list of IXC trunks, (2) using the Transit Network Selection (TNS) or Carrier Identification Code (CIC) parameters contained within the SS7 IAM message to identify the requested IXC, and (3) using the destination point code (DPC) from the SS7 IAM message to identify calls routed to IXC's

Identification of Non-transit Inbound from CLEC to LEC calls can be performed by (1) using a look-up table to map the specific trunk used on a terminating LEC call

(derived from another look-up table mapping the triplet of OPC, DPC and TCIC, which are available within the SS7 IAM message) to a list of CLEC and (2) using the origination point code (OPC) from the SS7 IAM message to identify calls originating from CLEC's.

5

7. Statistical Analysis Methods:

In representative embodiments, there are two typical approaches to arbitrage detection using statistical analysis: (1) single-carrier and (2) multi-carrier.

7.1 Single Carrier:

The basic approach to arbitrage detection using this statistical analysis method is to characterize the traffic between two carriers based upon the following criteria and compare the results to the following characteristics which are often present in known arbitrators: (1) Percentage of calls where forward or backward interworking bit **T140,T150** is set which implies that the call traversed a non-SS7 network, (2) percentage of calls wherein calling party information is available, (3) percentage of calls terminating to the ILEC, (4) percentage of calls where jurisdiction indicator parameter is available, (5) percentage of calls where carrier identification code is available, and (6) number of NPA's associated with the Calling Party Information.

Figure 6 is a flow chart of a method for establishing a probability of arbitrage in the telephone or similar communication system **100** as described in various representative embodiments of the present patent document. When the forward interworking parameter **T140** is used to establish a measure of the probability of call mis-routing, block **610** transfers control to block **611**. Otherwise block **610** transfers control to block **620**.

In block **611**, the percentage of calls wherein the forward interworking parameter **T140** is set is established. Block **611** then transfers control to block **620**.

When the backward interworking parameter **T150** is used to establish a measure of the probability of call mis-routing, block **620** transfers control to block **621**. Otherwise block **620** transfers control to block **630**.

In block **621**, the percentage of calls wherein the backward interworking

parameter **T150** is set is established. Block **621** then transfers control to block **630**.

When calling station information **T110** availability is used to establish a measure of the probability of call mis-routing, block **630** transfers control to block **631**. Otherwise block **630** transfers control to block **640**.

5 In block **631**, the percentage of calls wherein availability of calling station information **T110** is established. Block **631** then transfers control to block **640**.

When call ending in an ILEC **330** is used to establish a measure of the probability of call mis-routing, block **640** transfers control to block **641**. Otherwise block **640** transfers control to block **650**.

10 In block **641**, the percentage of calls terminating in an independent local exchange carrier (ILEC) **330** is established. Block **641** then transfers control to block **650**.

When jurisdiction indicator parameter information **T130** availability is used to establish a measure of the probability of call mis-routing, block **650** transfers control to block **651**. Otherwise block **650** transfers control to block **660**.

15 In block **651**, the percentage of calls wherein availability of jurisdiction indicator parameter information **T130** is established. Block **651** then transfers control to block **660**.

When carrier identification parameter **T160** availability is used to establish a measure of the probability of call mis-routing, block **660** transfers control to block **661**. Otherwise block **660** transfers control to block **670**.

In block **661**, the percentage of calls wherein availability of carrier identification parameter **T160** is established. Block **661** then transfers control to block **670**.

25 When calling station area code **T110** is used to establish a measure of the probability of call mis-routing, block **670** transfers control to block **671**. Otherwise block **670** transfers control to block **680**.

In block **671**, the number of calling station area codes **T110** is established.. Block **671** then transfers control to block **680**.

30 In block **680**, the results of the above blocks are combined to obtain a measure of the probability of mis-routing of calls.

A measure of the probability of arbitrage is based upon the combinations of characteristics that are present. Once suspected, SS7 call detail records are randomly chosen and compared with billing records to confirm arbitrage. Once arbitrage is confirmed, the characteristics of known arbitrators can be further refined.

5

7.2 Multi-Carrier:

The multi-carrier approach to arbitrage detection relies on the creation of "traffic profiles" associated with each of the interconnecting carriers. These traffic profiles contain historical traffic information including the daily, weekly and monthly amount of traffic; traffic distribution in both directions as a function of the hour of the day; traffic distribution by switching office and or by trunk groups, etc.

Figure 7 is a flow chart of another method for establishing a probability of arbitrage in the telephone or similar communication system **100** as described in various representative embodiments of the present patent document. In block **710** a historical profile of first and second connecting carriers **330** is created, wherein first and second carriers **330** connect to the same local area exchange **325**. Block **710** then transfers control to block **720**.

In block **720** the degree to which traffic profiles change inversely to each other is computed. Block **720** then transfers control to block **730**.

In block **730** a measure of probability of call mis-routing is established based on the results of block **720**.

Arbitrage may be suspected whenever the traffic profiles of two or more carriers change in ways inversely proportional to each other, suggesting the redirection of traffic from one carrier to another. Once suspected, SS7 call detail records can be analyzed in further detail to confirm the arbitrage.

8. Concluding Remarks:

Previous methods for the determination of telephone traffic mis-routing have proven to be ineffective in determining the presence of arbitrage and to be often lacking in accuracy for billing purposes due in large part to limitations in the data that they use. Embodiments disclosed in the present patent document overcome these limitations by

collecting call detail records from various points in the telephone system, correlating these records, and then analyzing them. Such techniques have a greatly enhanced probability of probability of detecting arbitrage and billing accuracy. Call detail records **T100** missing data can be enriched by data from related records **T10** in the correlation process.

While the present invention has been described in detail in relation to preferred embodiments thereof, the described embodiments have been presented by way of example and not by way of limitation. It will be understood by those skilled in the art that various changes may be made in the form and details of the described embodiments resulting in equivalent embodiment that remain within the scope of the appended claims.

00/01/11 05:50/00

initial address message (IAM) timestamp [T210]	The time the trunk was seized
address complete message (ACM) timestamp	The time the called telephone began ringing
answer message (ANM) timestamp [T230]	The time the called telephone was answered
release message (REL) timestamp [T220]	The time the first of either the called or calling telephone was hung up.
Release complete message (RLC) timestamp	The time the second of the called or calling telephone was hung up.

Table 2